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Impact of joint theater trauma system initiatives on battlefield injury outcomes

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Abstract

INTRODUCTION: The US military forces developed and implemented the Joint Theater Trauma System (JTTS) and Joint Theater Trauma Registry (JTTR) using US civilian trauma system models with the intent of improving outcomes after battlefield injury.

METHODS: The purpose of this analysis was to elaborate the impact of the JTTS. To quantify these achievements, the JTTR captured mechanism, acute physiology, diagnostic, therapeutic, and outcome data on 23,250 injured patients admitted to deployed US military treatment facilities from July 2003 through July 2008 for analysis. Comparative analysis to civilian trauma systems was done using the National Trauma Data Bank (NTDB).

RESULTS: In contrast to civilian trauma systems with an 11.1% rate of penetrating injury, 68.3% of battlefield wounds were by penetrating mechanism. In the analyzed cohort, 23.3% of all patients had an Injury Severe Score (ISS) $\geq$16, which is similar to the civilian rate of 22.4%. In the military injury population, 66% of injuries were combat-related. In addition, in the military injury group, 21.8% had metabolic evidence of shock with a base deficit $\geq$5, 29.8% of patients required blood transfusion, and 6.4% of the total population of combat casualties required massive transfusion (>10 U red blood cells/24 hours). With this complex and severely injured population of battlefield injuries, the JTTS elements were used to recognize and remedy more than 60 trauma system issues requiring leadership and advocacy, education, research, and alterations in clinical care. Of particular importance to the trauma system was the implementation and tracking of performance improvement indicators and the dissemination of 27 evidence-based clinical practice guidelines (CPGs). In particular, the damage control resuscitation guideline was associated with a decrease in mortality in the massively transfused from 32% pre-CPG to 21% post-CPG. As evidence of the effectiveness of the JTTS, a mortality rate of 5.2% after battlefield hospital admission is comparable to a case fatality rate of 4.3% reported in an age-matched cohort from the NTDB.

CONCLUSIONS: JTTS initiatives contributed to improved survival after battlefield injury. The JTTS has set the standard of trauma care for the modern battlefield using contemporary systems-based methodologies. Published by Elsevier Inc.

Many important medical lessons were learned by the military during the course of the Vietnam War, particularly helicopter transport with the attendant decreases in time from injury to definitive treatment. At the same time, the Institute of Medicine published its perspective on the impact

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of injury as a health care issue within the United States. After these challenges, civilian emergency medical services and trauma centers were initiated. The focus of trauma care has gradually evolved from the concept of an isolated trauma center to that of a trauma care system with substantial proponency by the American College of Surgeons whose document "Resources for the Optimal Care of the Injured Patient" formed the basis for modern trauma systems.[1] The trauma system is defined as an organized effort in a geographic region to deliver a full range of trauma care. The goal of the system is to improve transition and continuity of care.[2] Assessment of the effectiveness of trauma systems substantiated a mortality benefit of 15%–20% in regions covered by a comprehensive trauma system.[3–11]

To mimic civilian trauma system outcome successes, the Joint Theater Trauma System (JTTS) was developed as systematic and integrated approach to better organize and coordinate battlefield care to minimize morbidity and mortality and optimize the ability to provide essential care required for casualty injuries. The JTTS was promulgated to improve battlefield trauma care through enabling the right patient, to the right place, at the right time, to receive the right care (R4). The components of the JTTS system include prevention, pre-hospital integration, education, leadership and communication, quality improvement/performance improvement, research, and information systems. The purpose of the present analysis was to elaborate the impact of the JTTS.[12,13]

Methods

To quantify the epidemiology and outcomes of military injury, acute physiology, diagnostic, therapeutic, and outcome data on 23,250 injured patients admitted to deployed US military treatment facilities were captured in the Joint Theater Trauma Registry (JTTR) from July 2003 through July 2008 for analysis. Comparative analysis to civilian trauma systems was done using a commensurate time period from the National Trauma Data Bank (NTDB) of the American College of Surgeons and contemporary literature on civilian trauma patients. Analysis of JTTS impact was performed by multiple methodologies. The impact of JTTS-disseminated evidence-based clinical practice guidelines was evaluated by demonstration on clinical outcomes both before and after institution of clinical practice guidelines, as well as guideline compliance.

Results

Military/civilian comparison

In contrast to civilian trauma systems with an 11.1% rate of penetrating injury, 68.3% of battlefield wounds were by penetrating mechanism, of which 67% were caused by the secondary fragment injury from explosive agents. In the analyzed cohort, 23.3% of all patients had an Injury Severe Score (ISS) ≥16, which is similar to the civilian rate of 22.4%. In the military injury population, 66% of injuries were combat-related. In addition, in the military injury group, 21.8% had metabolic evidence of shock with a base deficit ≥5, 29.8% of patients required blood transfusions, and 6.4% required massive transfusion (>10 U red blood cells/24 hours). Substantiating the difference in patient characteristics, in 1 analysis of 15,534 trauma patients in the civilian environment, the rate of transfusion was 10.9% and massive transfusion 2.7%.[14] As evidence of the effectiveness of the JTTS, a mortality rate of 5.2% after battlefield hospital admission is comparable to a case fatality rate of 4.3% reported in an age-matched cohort from the NTDB (Table 1). With this complex and severely injured population of battlefield injuries, the JTTS recognized and remedied more than 60 trauma system issues requiring leadership and advocacy, education, research, and alterations in clinical care.

Table 1 Comparison of civilian and military injury

	Civilian literature	NTDB	JTTR
Blunt mechanism		88.9%	31.7%
Penetrating mechanism		11.1%	68.3%
ISS ≥16		22.4%	23.3%
Base deficit ≥5			21.8%
Blood transfusion	10.9%		29.8%
Massive transfusion	2.7%		6.4%
Hospital death after admission		4.3%	5.2%

Evidence-based practice

Of particular importance to the trauma system was the implementation and tracking of performance improvement indicators and the dissemination of 27 evidence-based clinical practice guidelines (CPGs). The impact of CPGs was demonstrated with respect to hypothermia prevention and management after injury, burn resuscitation, and massive transfusion outcomes. As an adjunct to this analysis, guideline compliance was documented after institution of the clinical practice guidelines. All 3 guidelines analyzed demonstrated significant improvements in outcome associated with a high rate of CPG compliance (Table 2).

Comments

In 1996, the Government Accountability Office (GAO) report addressed shortfalls identified from Operation Desert Storm, including:

". . . shortcomings in DoD's [Department of Defense's] ability to provide adequate, timely medical support during

Table 2 Impact of evidence-based clinical practice guidelines

	Pre-CPG	Post-CPG	*P*	CPG Compliance
Burn resuscitation-associated abdominal compartment syndrome mortality (burn CPG)	36%	18%	<.05	94%
Hypothermia on presentation (hypothermia CPG)	7%	1%	<.05	84%
Massive transfusion mortality (≥10 U RBCs/24 h) (damage control resuscitation CPG)	32%	20%	<.05	85%

RBCs = red blood cells.

contingencies and problems with the planning and execution of these efforts. The Joint Staff also identified problems with the current design of DoD's wartime medical system. In response to these problems, DoD and the services embarked on initiatives to correct shortfalls in wartime medical capabilities and improve medical readiness."[15]

The Skamania Consortium in 1998 brought the concept of trauma system impact to the forefront of trauma medicine. Evaluating the composite of panel studies, comparison of national injury registries and population-based studies uniformly demonstrated a 15%–20% reduction in risk of death after trauma center admission.[3–11] This beneficial effect of trauma systems was a prime motivation for the development of the JTTS after the inception of military contingency operations consequent to the events of September 11, 2001. After 5 years of JTTS development and implementation, the current study was undertaken to evaluate the impact of several specific trauma system activities within the program.

There were notable similarities and contrasts between the civilian and military trauma systems. Mechanism of injury in the combat environment was largely penetrating mechanism in contrast to the civilian cohort. In addition, the substrata of explosive injury was almost exclusively unique to the military population. Despite these similarities, the number of high acuity casualties as scored by ISS was not significantly different between the groups. However, several authors suggest that the ISS does not adequately represent injury severity in penetrating injury.[16–18] To further substantiate the severe nature of the battlefield injury, 21.8% of casualties presented with metabolic evidence of shock and 29.8% required blood transfusion. Of the transfused casualties, 21.5% required transfusion of >10 U of blood in 24 hours (6.4% of the total population). Civilian analysis of transfusion rates underscores the high acuity injury of the combat casualty.[14] Despite the high acuity of battlefield casualties, the JTTR documented in-hospital death rates similar to those in the NTDB. Interestingly, the NTDB documented a 15.9% in-hospital mortality rate for victims of penetrating injury. The 5.2% rate of patients who died of wounds after hospital admission in the military population, of which two thirds are penetrating injuries, validates the success of acute care facility medical care in the combat theater.

CPGs are evidence-based outlines of accepted management approaches that may be disease-, problem-, or process-specific; they are systematically developed statements that are used to assist practitioner and patient decisions about appropriate healthcare for specific clinical circumstances. The goals of such guidelines are to identify all treatment options and possible outcomes, and to weigh the benefits against the risks and costs. Ideally, CPGs are derived from the data sources available and used to guide healthcare professionals through a continuous quality-improvement effort in which the process involved in healthcare delivery is analyzed, changes recommended, and patient outcomes defined.[19] The concept of developing trauma management clinical practice guidelines was popularized by the Eastern Association for the Surgery of Trauma in the late 1990s. The notion of combat trauma clinical practice guidelines was particularly novel in the development of the JTTS since very little data were available from large-scale military conflict. Many of the clinical practice guidelines were extrapolated from the civilian trauma realm and attempts were then made to translate them into realistic and relevant treatment practices within the military realm. Others were developed due to their specific relevance to combat casualty care. Little published data in the trauma literature defines the outcomes of evidence-based CPGs. Our current analysis was able to demonstrate the impact of evidence-based trauma medicine guidelines by substantiating improvements in outcome for burn resuscitation-related mortality, damage control resuscitation mortality, and hypothermia prevention and management after injury in the context of guideline compliance. The success of pre-deployment educational efforts and peer review manuscripts further substantiate the evolving impact of the JTTS. One very important aspect of this analysis is that it transcends the noted limitation in many previous studies of a reliance on acute survival as a sole measure of trauma system effectiveness.

Related to the evidence-based practice sustainment was the novel development of a global performance improvement program that was built on a rudimentary telecommunications platform. A weekly teleconference was an extremely valuable tool for communication of individual patient issues along the evacuation continuum, as well as for providing valuable feedback to providers within the chain. Such a concept may have applicability for rural trauma systems in civilian practice or for domestic mass casualty scenarios. In addition, a monthly teleconference was used to identify larger, more systemic issues, and elaborate unified and evidence-based clinical and operational solutions. Further measures of the JTTS program's medical performance

improvement utility extended beyond the bounds of the highlighted impacts in this analysis. Contemporary data from the JTTS was used to develop and implement a predeployment medical training course, the Joint Forces Combat Trauma Management Course, for physicians and nurses, which to date has trained 1,153 providers. Of the trainees, 87% noted that the combat trauma management course improved preparation for the combat medical mission. In addition, the JTTR was used to publish more than 152 peer-reviewed manuscripts in the surgical literature, publications that educate subsequent providers deploying to care for the war-injured.

It should be noted that the improved outcomes of combat wounding are not solely the direct result of the JTTS initiatives. Two particular concurrent military advances, personal protective equipment and new paradigms of pre-hospital care, also significantly impacted combat casualty care.

JTTS initiatives contributed to improved survival after battlefield injury. The JTTS has set the standard of trauma care for the modern battlefield using contemporary systems-based methodologies and will continue to foster advances in military medicine. Some of these advances may be translatable into civilian practice.

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Discussion

Dr Daniel Vargo (Salt Lake City, UT): Our military colleagues have brought much to the table in the past few years. It is appropriate now that civilian trauma provides something back to the military experience in the form of performance improvement, review and evaluation of data to come up with clinical guidelines. That has been the core of trauma system development in the civilian world where the main part when we review trauma centers right now is to look at performance improvement and to make sure that systems are maturing. What is impressive is the improvement that you have seen in some of your care guidelines that you have implemented, specifically your burn resuscitation guideline showing a significant improvement. What I thought was kind of interesting looking at the manuscript was that there was not 100% compliance, this being the military, for your guidelines. We could just take people and make them take more trauma calls; I guess you guys sort of take people and shoot them. So with that, I have 4 questions: The National Trauma Database and its associated guidelines are 1 starting point for trauma care, but there are other databases such as Project Impact (PI) for surgical intensive care unit care that can be utilized. Have you looked at any of these other databases to see if you can adapt them to the military environment? How do you PI such a large system? That might be too broad of a question to address in this forum, but I find it interesting that you do have these multiple areas that you have to try and PI. While death is always an important primary outcome measure, were you looking at any other outcome measures as far as disability and return to function and so forth as this system matures? That would be something that we would expect in the civilian environment as the system matures. And lastly, are you doing anything to improve compliance with your guidelines? So, again, this was a very nice submission and a very good presentation.

Dr Eastridge: First, I would like to thank Dan for his insightful comments about our work. First, the comparison

with the National Trauma Databank and our registry, it was really made to illuminate and illustrate the volume and the complexity of our patient population. The education and publication notation illustrates the impact on the conveyance and dissemination of new medical information across a broad discontinuous environment. With respect to question one, we did not use any other databases. As a side note, we are actively developing 13 subspecialty modules off the registry so that we can look at how to best evaluate subspecialty elements of care. How do we pursue large-scale PI? That is an excellent question. What we have done is work with our Information Management/Information Technology community and we have had a very vigorous push toward telemedicine. Across the breadth of the system, we do weekly teleconferences discussing all the patients in the system that week. We also have a monthly system performance improvement review where we look at more systemic issues. We actually have a fielded team. I have 11 people deployed at theater right now and they are in the main hub hospitals. They are not only responsible for collecting and collating some of these data, but another of their key roles at this point is to take that information we analyze and put it back out to the providers in terms of feedback to augment performance improvement. We actually have had several meetings with the American College of Surgeons Committee on Trauma and they are very interested in this aspect of our process, perhaps for potential utilization in homeland defense for mass casualty and disaster management. Non-death outcomes: we are very interested in non-death outcomes. We are looking at the rate of hypothermia and compartment syndrome. We are looking at the evaluation of the topic of infection control—on how that affects and mitigates infectious outcomes. We also have a very active partnership with the Center for the Intrepid, the VA Medical Center to look at rehabilitation type outcomes. And with respect to your last question about the guidelines, we specifically do not want to make them policy because of perceptions in the military environment, we do not want to make medicine coercive. Is there a process to deal with outliers? If somebody is grievously making mistakes, we have a medical process and a command process to take those elements out of the loop, but generally and luckily it does not happen that often. But over the course of 5 years, we have had a dramatic increase in our partnership with providers in the field, so they are very open-minded about taking the clinical practice guidelines and running with them when they are deployed.

Dr Fred Moore (Houston, TX): I had the pleasure of participating in the Senior Visiting Trauma surgeon program at Landstuhl Medical Center in Germany last year and I was very impressed with the whole operation, especially the weekly telemedicine performance improvement meetings. I want to make a little comment on compliance to protocols because your rate of compliance is unbelievable. If you look in the literature, there was a study by McGlynn concerning the quality of health care in the US published in *New England Journal of Medicine* in 2003, which demonstrated only 55% of patients actually get the care they are supposed to get. More recently, the surviving sepsis campaign spent 2 years trying to implement their evidence-based guidelines in 166 hospitals; compliance with their resuscitation bundle rose to only 31% and compliance with the early management bundle rose to only 36%. The only way that I know to get protocol compliance over 95% is use computerized clinical decision support. So I want to know how did you monitor compliance? How did you feed that back to the providers? How detailed was the feedback?

Dr Eastridge: With respect to the burn resuscitation protocol, it was basically whether or not they followed the burn resuscitation guidelines and used the burn resuscitation flow sheet and so that we were able to track that back at the Brook Army Medical Center (BAMC) with respect to basically utilization of the burn flow sheet and did they follow the burn resuscitation algorithm. We have fairly good capture, particularly in that setting since we get all the burns at BAMC. We are able to capture that data with pretty good fidelity. The hypothermia metric was basically evaluating casualties in the field that had appropriately applied hypothermia prevention and management devices and again, we can track that with some degree of fidelity. We have 21 clinical practice guidelines that we are really wrestling with. Those are the ones that I did not present today, not only to improve compliance, but also to gauge their effects.

Dr Steve Smith (Roanoke, VA): I want to compliment you on some excellent work. I also spent 2 weeks as a visiting surgeon at Landstuhl and the things that you guys have done there are truly remarkable and the Thursday PI session with the downrange facilities I think can serve as a model for all of us. My question has to do with the fidelity of your data acquisition system at this point. Obviously, Iraq is not Afghanistan and vice versa. It is my understanding that the time from initial wounding to initial care is different in Afghanistan as compared to Iraq. Have you been able to tease out the differences in those 2 locales to make changes in your protocols based on data?

Dr Eastridge: Actually, we have. That is a very good question. Some of the work that we do is under the purview of the confidentiality and resides in the secret domain. However, to illustrate 1 impact, we looked at the impact of rotary wing medical evacuation from both parts—Afghanistan and Iraq. There was a significant disparity between Afghanistan and Iraq and due to the importance of this information, that information went right to the Secretary of Defense. As a result, the Secretary of Defense mandated increases in air evacuation and medical assets in Afghanistan.

Dr Rifat Latifi (Tucson, AZ): You mentioned telemedicine a couple of times. Are you using it for education of the healthcare providers in the field or just for videoconferencing on the administrative level? In other words, are you using telemedicine aspect or telemedicine technology to actually educate the young recruits or the new doctors,

nurses in the field or using it just for the administrative issues?

Dr Eastridge: The question was regarding telemedicine or telepresence. We use telemedicine or telepresence in a 2-fold way. One is the way I alluded to where we have an ongoing dialogue about the patients who are in the system at the time and that portal is managed through the system. There is also a very active telepresence/teleconsultation module. We have about 20 different consultant services and they each have a panel. So when there is a provider in theater that has a question about a rash or a burn or a medical management issue with which they are not familiar, they put that into the telepresence system and there is a provider back here in the states that manages and looks at the telepresence system 24/7 so that we could provide them relatively real-time consultation.